Cattle grazing tall larkspur on Utah mountain rangeland

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Abstract

Ingestion of tall larkspur (*Delphinium barbeyi* L. Huth) is a major cause of cattle death on ranges where the plant occurs. The amount and timing of tall larkspur ingestion by grazing cattle was studied from 30 July to 2 September 1986 on high mountain rangeland in central Utah. Forbs dominated the vegetation and were also the major dietary item selected by cattle (>70% of total bites). There was a negative relationship (r=-0.62) between standing crop of other forbs and tall larkspur consumption. Cattle began eating substantial quantities (>10% of bites) of tall larkspur about 10 August, and consumption had increased to 20% when the study ended. Tall larkspur leaves and pods were the major parts selected. At the time of major consumption, leaves were relatively low and declining in total alkaloid concentration (TAC) (1.0–0.6%) while pods were approximately 1.0% TAC and increasing when the study ended. Time spent per feeding station (TFS) was influenced by the vegetation area where animals foraged. TFS in the grass-forb, currant (*Ribes* spp.), and larkspur areas were 11.2, 25.9, and 22.0 s, respectively. Cattle grazed most efficiently (bite rate:step rate) in the grass-forb areas, and least efficiently in the currant areas. Cattle ate large quantities of tall larkspur during the study with no deaths, probably due to the low alkaloid levels in the tall larkspur. Larkspur consumption was not correlated with previous 12- or 24-h precipitation totals. However, cattle did begin major consumption of tall larkspur after 2 rain showers fell following a several week dry period.

Key Words: poisonous plants, alkaloids, larkspur grazing, cattle grazing behavior

Larkspur (*Delphinium* spp.) poisoning is a major cause of livestock losses on mountain ranges (Williams and Cronin 1966). Cronin (1971) reported that tall larkspur was responsible for more cattle *(Bos taurus)* losses in central Utah than all other poisonous plants. Even though cattle typically graze these mountain ranges for short periods of time during the summer, death losses attributed to larkspur poisoning have been severe (2 to 12%, mean 4.3%) for some USDA Forest Service grazing allotments experiencing persistent losses (Cronin et al. 1976). Cattle losses on high (>3,000 m) mountain ranges generally are greatest during the first 2 to 3 weeks of the grazing season (Williams and Cronin 1966, Knowles 1974). Other work indicates a bimodal peak to losses, with some deaths occurring during the latter portion of the grazing season (Cronin et al. 1976).

The toxic components of tall larkspur are alkaloids. Ingestion of toxic quantities of larkspur progressively induces restlessness, stiff movements, then a straddled stance before sudden collapse (Olsen 1978). Death is from respiratory failure. Early studies suggested that toxicity of larkspur plants is related to stage of growth (Marsh et al. 1916). Williams and Cronin (1966) found the plant highest in alkaloid levels during the early stages of growth, with new leaves and stem tips containing high concentrations of alkaloids. Studies with rats indicated that toxicity declines with maturity; however the seeds are high in alkaloids (Olsen 1977). Larkspur toxicity cannot be related directly to total alkaloid levels. Individual alkaloids, or combinations of alkaloids vary in degree of toxicity (Olsen 1984).

Little information exists on the amount and timing of larkspur ingestion by grazing cattle. Feeding trials in pens have shown the quantities of tall larkspur that are fatal to cattle, and have characterized the symptoms of larkspur poisoning (Olsen 1978). However, research into plant/animal relationships under grazing situations is needed so that management strategies to prevent or reduce losses can be formulated and tested (Cronin et al. 1976, Olsen 1984). Thus, the objectives of this study were (1) to determine when cattle consumed larkspur in relation to plant phenology and alkaloid levels of plant parts, (2) to determine if a relationship existed between larkspur consumption and standing crop of other available forages, and (3) to quantify aspects of cattle foraging behavior on larkspur-infested rangelands.

Methods

The field study was conducted at the head of Six Mile Canyon, east of Manti in central Utah at an altitude of about 3,200 m. Two habitat types are found on the study area (Bob Thompson, Range staff officer, USDA Forest Service, personal communication). The first is a *Ribes-Agropyron* dominated site, with open grass-forb areas interspersed with dense mottes of currant (*Ribes* spp.). Important grasses in this type are slender wheatgrass *(Agropyron trachycaulum* (Link) Malte), mountain brome (*Bromus carinatus* Hook. & Arn.), and Lettermans needlegrass (*Stipa lettermannii* Vasey). Dominant forbs in this type are Louisiana sagebrush (*Artemisia ludoviciana* Nutt.), mountain dandelion (*Taraxacum officinale* Weber), plantain (*Plantago tweedyi* Grey), and meadow rue (*Thalictrum fendleri* Engelm.). The second habitat type is found on snowdrift areas and is dominated by dense concentrations of tall larkspur. Besides tall larkspur, vegetation in this type consists of sparser quantities of the same major grasses and forbs as found in the *Ribes-Agropyron* type. At the beginning of the study, tall larkspur plants were in various stages of growth from vegetative in areas of recently melted snow to flowering in areas where lesser amounts of snow had accumulated. Soils in the area were montmorillonitic, clayey-skeletal, Pachic Cryoborolls on benches hosting the tall larkspur-dominated tall forb community. Soils were eroded to very shallow solas deposits among coarse limestone cobbles on the slopes (Dan Larsen, soil scientist, USDA Forest Service, personal communication).

The 4-ha study pasture was enclosed with an electric fence. Sufficient forage was available for 4 yearling Hereford heifers (350 kg body weight) to graze the site from late July to early September, 1986. The heifers had grazed in the area the previous summer as calves with their mothers. A bite count technique was used in conjunction with focal animal sampling (Altman 1974) to determine relative amounts of tall larkspur consumed. Each heifer was observed for two, 10-minute periods during the morning beginning just after daybreak. During the afternoon and evening each heifer was observed for three or four 10-minute periods. Bites were recorded in the following categories: tall larkspur leaf, flowering raceme, pod raceme, and stem, grasses (including grasslike), Louisiana sagebrush, *Lupinus* spp., other forbs, and the shrubs currant and elderberry (*Sambucus racemosa* L.).

Average daily grazing time was determined by fitting a heifer with a vibracorder. Time per feeding station (TFS) was determined every 10 days. A feeding station was defined as the amount

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of time an animal spent grazing at a site without moving both front feet (Ruyle and Dwyer 1985). Each heifer was observed during the morning grazing period until 25 feeding stations were recorded. The process was repeated during the afternoon. Simultaneous measurements were made of the steps taken between feeding stations, and the time spent walking between feeding sites. The vegetation area the animal was grazing in was also noted (e.g., currant, grass-forb, or larkspur areas).

Larkspur plant parts were collected periodically for alkaloid analysis. Clipped samples were oven-dried at 60° C and 48 h. A wet weight was taken at the time of harvest to determine dry matter percentage of larkspur throughout the grazing period. The plant material was ground through a 1-mm screen in a Wiley mill and analyzed for total alkaloid concentration (TAC). TAC was determined using a modification of the procedure of Pelletier et al. (1981). HCl was used after ethanol extraction to acidify the extract, and NaOH was used to basify the aqueous layer after extraction with chloroform.

A stratified random sampling scheme was used to determine standing crop. The study area was mapped into 3 discrete plant communities. The *Ribes-Agropyron* type was divided into 2 areas dominated by currant mottes and grass-forbs, respectively. The third plant community consisted of the area dominated by tall larkspur. The grass-forb area was sampled using thirty .25m by 1m-quadrats clipped to 15-mm stubble height at the beginning, midpoint and the end of the trial.

Tall larkspur biomass was determined using a double-sampling procedure. Ten tall larkspur plants were randomly selected along a transect line, the stalks were counted, then a visual weight estimate of each plant was recorded before clipping and weighing. An additional 30 tall larkspur plants were similarly selected, and after counting the number of stalks, a weight estimate was made of each plant. Weights of the 30 estimated plants were corrected with a regression procedure using the first 10 plant weights and estimates. This regression equation was $Y=40.23+1.001X$ ($r^2=.69$, $P=0.0028$), were X is the estimate of larkspur weight and Y is the corrected weight estimate per larkspur plant. Density of larkspur plants on the area was determined using thirty 2m by 4-m plots located along transects in the areas dominated by larkspur. Total larkspur standing crop was then calculated as the weight per plant multipled by the density. This procedure was done only at the beginning of the grazing trial because it became obvious that this procedure was not sensitive to larkspur disappearance over time since cattle grazed only racemes and leaves. No estimation was attempted of the available forage in the very dense currant mottes. There were few other forage species in the dense larkspur areas, thus no additional standing crop measurements were taken.

Utilization of tall larkspur was estimated midway through the study (16 August) and again at the end of the trial (3 September). Forty 1-m^2 plots were randomly located along transects in the larkspur areas. Within each plot, measurements taken included the number of stalks, the number of grazed stalks (apex or leaves removed), and the number of remaining ungrazed flowers or pods (intact apexes).

Rainfall was measured using a precipitation event recorder. Each rainfall event was recorded automatically on a chart which was read daily. Temperature and relative humidity were continuously recorded using a hygrothermograph.

Statistical analysis involved calculating confidence intervals, and *t*-tests where appropriate. Chi-square analysis was used to test for differences in the histograms of TFS and bite rate by vegetation area or date.

Results

Forage available

Forbs were the dominant component of the standing crop (Table 1). Louisiana sagebrush and *Lupinus* spp. were weighed separately due to their relative unpalatability to cattle. There was a significant ($P<0.1$) disappearance of other forbs over time. Graminoids actually increased slightly ($P>0.1$) during the first 2 weeks, then declined ($P>0.1$) during the latter portion of the study. Tall larkspur biomass was 1,330 kg/ha when averaged over the entire study area. However, in the dense patches tall larkspur biomass was nearly 5,000 kg/ha. Larkspur plant parts did not change greatly in moisture content over time. The leaves, flowering racemes, and fruit pods were 75 to 81, 73 to 81, and 78 to 82% water, respectively, during the study period.

Table 1. Standing crop of herbage (kg/ha) on 3 dates on Utah mountain rangeland during 1986.

Item	Date		
	30 July	14 August	3 Sep.
Graminoids	232a	336a	180a
Other forbs	596a	440b	196c
A. ludoviciana	200	184	264
L. alpestris	60	36	48
SUBTOTAL	1088a	996ab	688b
D. barbeyi	1334	–d	–d

[abc]Means in the same row followed by a common letter have overlapping 90% confidence intervals.
[d]*D. barbeyi* was not measured on these dates; see Table 2 for utilization estimates.

Utilization of Tall Larkspur

Midway through the grazing trial only 15% of the larkspur apexes had been grazed, in contrast to 61% at the end (Table 2). No larkspur stalks with grazed leaves were noted at the mid-point, although cattle had been observed eating a few leaves during the previous week. By the end of the study, over 45% of the stalks had at least 1 grazed leaf. At the midpoint of the trial, most of the ungrazed stalks were in the flower stage (63%) (Table 2), compared to 36% in the pod stage. At the end of the trial, 79% of the ungrazed stalks were in the pod stage. Utilization estimates suggest preference for pods over flowers.

Table 2. Utilization of larkspur (means ± S.D.) by cattle at the midportion (16 Aug) and end (3 Sep) of the grazing period.

Item	Date	
	16 Aug	3 Sep
% grazed larkspur apexes[c]	15.2±20.4a	61.2±25.5b
% stalks with ≥1 grazed leaf	0.0a	45.2±30.7b
% ungrazed apexes with flowers	63.1±31.9a	14.7±12.4b
% ungrazed apexes with pods	35.7±34.6a	79.0±29.4b

[ab]Means in the same row with different letters are different ($P<.05$) as determined by t-test.
[c]Virtually all grazed apexes (flower or pod) were utilized 80–100% (i.e. little residual flower or pod on apex).

Total Alkaloids in Tall Larkspur

Plant parts differed in TAC according to phenological stage of the individual plant on a given date (Table 3). On 1 Aug., leaves from vegetative larkspur plants were highest in TAC (>3.0%), while leaves from plants in full bloom had much lower TAC (1.0%). TAC for stems from vegetative plants were also much higher compared with stem material from flowering plants. Flowers showed an increase in TAC from the bud to full bloom stages of growth. Pods were about 1% TAC near the end of August, and were increasing when the study ended.

Bite Count

The cattle selected little (2.5% of total bites) tall larkspur during early days of the study (Table 4). The proportion of larkspur bites increased as the study progressed until >20% of the bites were

Table 3. Total alkaloid content for tall larkspur plant parts on Utah rangeland during August, 1986.

Plant part	Date	Phenological stage	Total alkaloids[a]
Leaf	1 Aug	vegetative	3.1
Leaf	1 Aug	bud	1.3
Leaf	1 Aug	full bloom	1.0
Leaf	25 Aug	fruit pod	0.6
Stem	1 Aug	vegetative	2.4
Stem	1 Aug	bud	0.6
Stem	1 Aug	full bloom	0.3
Stem	25 Aug	fruit pod	0.4
Flower	1 Aug	bud	0.6
Flower	1 Aug	full bloom	0.9
Flower apex[b]	15 Aug	full bloom	0.6c
Pod apex[b]	15 Aug	fruit pod	1.0c
Pod apex	25 Aug	fruit pod	0.9
Pod	25 Aug	fruit pod	1.2
Pod apex	28 Aug	fruit pod	1.2c

[a]% of dry matter.
[b]flower or pod apex = entire raceme including flower or pod, petiole and stem material.
[c]TAC determined according to method of Cundiff and Markunas (1955), as modified by Williams and Cronin (1963).

Table 4. Percent of bites during 3 periods[d] by cattle grazing larkspur-infested mountain rangeland.

	Days			
Item	1-9 (Early)	10-18 (Mid)	19-27 (Late)	Overall
Larkspur				
leaf	0.2a	5.5b	15.4c	7.0
stem	0.1	te	t	t
pod	1.0a	5.8b	5.0b	3.9
flower	1.2a	1.9a	tb	1.3
total	2.5a	13.2b	20.4c	12.0
Graminoids	20.5a	15.3ab	13.7b	16.5
Other forbs[f]	76.6a	70.9ab	65.1b	70.9
Shrubs	0.2a	0.5a	0.8a	0.4

[abc]Values in the same row with a common letter have overlapping 95% confidence intervals.
[d]Complete data sets (morning and afternoon observations for all animals) were available for 27 days. For this table the study was divided into 3 periods of 9 days each.
[e]t = trace (<0.1%).
[f]Includes *Artemisia ludoviciana* and *Lupinus alpestris*.

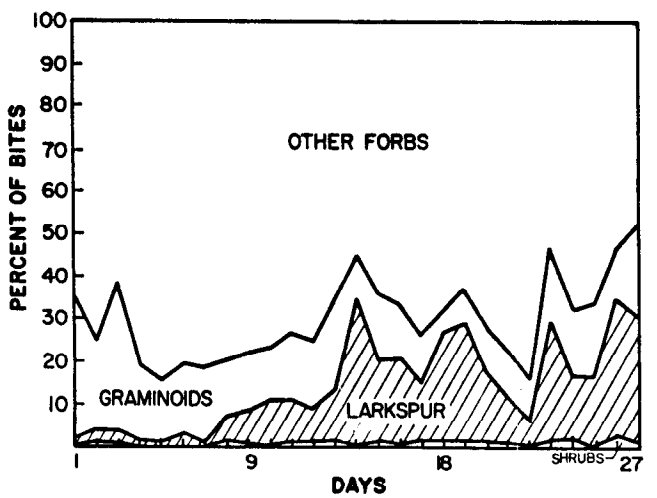

Fig. 1. *Percent of bites of tall larkspur, grasses, shrubs and other forbs taken by cattle on Utah mountain rangeland. Some days were deleted from the 30 July to 2 September trial because of incomplete observations for some animals.*

larkspur (Fig. 1). The selection of larkspur plant parts also changed over time. Cattle selected increasing amounts of larkspur leaf as the study progressed, and consumption of pods peaked midway in the trial and leveled off at about 5% of recorded bites (Table 4). Flower consumption was steady but very low (<2%) during the early and middle periods, and virtually disappeared as a dietary item by the end of the study.

Cattle consumed large quantities (>70% of bites) of other forbs during the study. Such forb consumption was unexpected because cattle are generally thought to be grass-preferring bulk and roughage eaters (Van Soest 1982). Preferred forbs were mountain dandelion, plantain, bluebells (*Mertensia* spp.), wild pea (*Lathyrus* spp.), and meadow rue. Graminoid consumption averaged 17% of bites overall, and decreased over time (Table 4). Consumption of

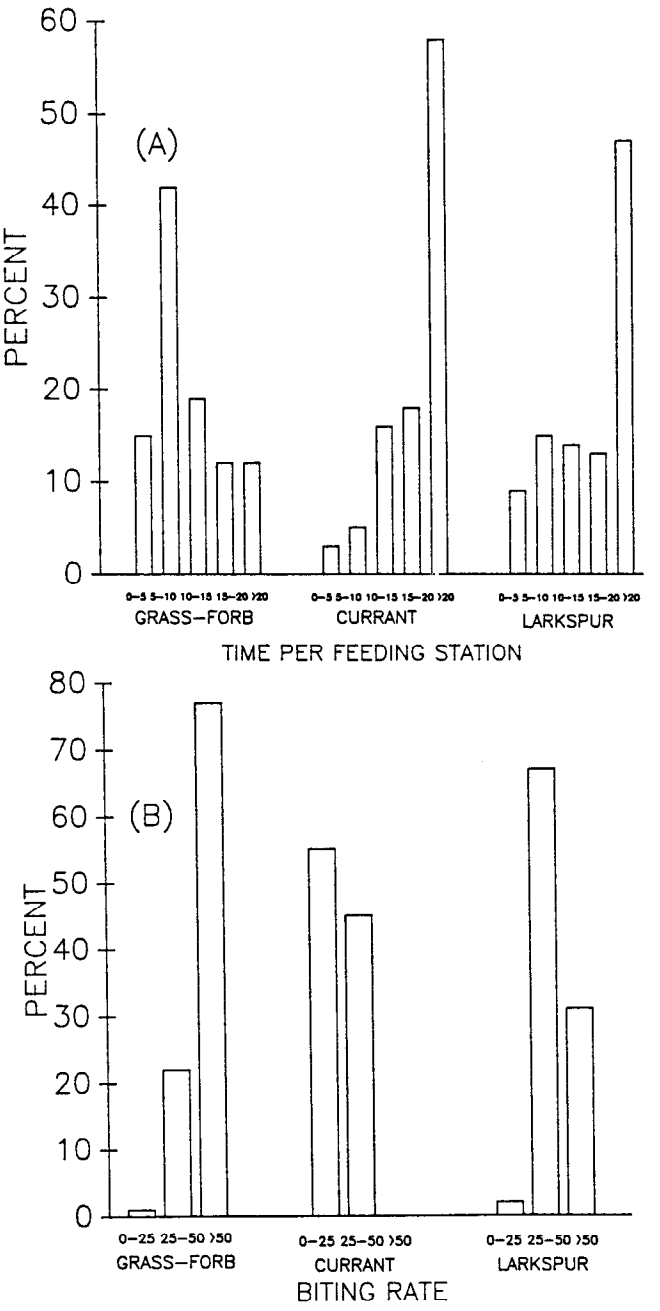

Fig. 2. *Histograms relating proportion (%) of (a) feeding station observations and class intervals (time spent per feeding station in seconds), and (b) biting rate observations and class intervals (bites/min) for 3 vegetation areas grazed on mountain ranges by cattle.*

Table 5. Means of behaviorial variables for cattle grazing larkspur rangelands by date and by vegetation area.

	Date				Vegetation		
	8 Aug	14 Aug	24 Aug	3 Sep	Grass-Forb	Currant	Larkspur
Time per feeding station (sec)	11.3a	13.8a	15.2ab	19.2b	11.2a	25.9b	22.0b
Bite rate (bites/min)	53.2ab	57.0b	56.7b	49.4a	64.4a	25.5b	46.0c
Step rate (steps/min)	79.1a	95.0a	85.8a	90.5a	91.5a	78.8b	86.8ab

[a,b,c]Means in the same row for dates or vegetation area with a common letter have overlapping 95% confidence intervals.

tall larkspur was negatively correlated with availability (kg/ha) of other forbs (excluding *Artemisia* and *Lupinus) (r*= –0.62, *P*= 0.0001) but not availability of graminoids (*r*= –0.14, *P*=0.15).

Anecdotal accounts of tall larkspur poisoning of cattle frequently mention a relationship between cattle deaths attributed to larkspur and rainfall events (Glover 1906). Correlations between the percent of larkspur bites and the previous 12- and 24-h precipitation (mm) had *r*-values of 0.14 and 0.23, respectively. Correlations between larkspur bites and daily maximum and minimum temperature and relative humidity gave *r*-values of –0.24, –0.12, –0.08, and 0.13, respectively. It is interesting to note, however, that larkspur consumption by the cattle increased after the first 2 recorded rainshowers on days 8 and 9 of the study following a dry period of several weeks. Later peaks in larkspur consumption were not consistent with rainfall patterns.

Feeding Stations

Time spent per feeding station (TFS) was influenced significantly by vegetation area where the animals were foraging (X^2=13.7, d.f.=8, P<0.001) (Fig. 2). Most feeding stations in the grass-forb area were of 5 to 10-second duration. Feeding stations were relatively long (>20 seconds; Table 5) in both the currant and larkspur areas. There was no change (P>0.05) noted in TFS in grass-forb or currant areas over time. However, there was an increase (P<0.05) in mean TFS for observations made in the larkspur areas from 11.0 seconds on 14 Aug. to 24.0 seconds on 1 Sept. In virtually all cases, animals were grazing on larkspur plants in larkspur areas as TFS observations were taken. Conversely in the currant area, cattle generally were eating forbs underneath the currant bushes, and rarely browsing the currant shrubs. There was a trend of increasing (P<0.05) TFS as the study progressed when averaged over all vegetation areas (Table 5).

Biting rate (bites/min) differed significantly by vegetation area also (X^2=363.0, d.f.=4, P<0.0001) (Fig. 2). Cattle increased biting rate while grazing the grass-forb area, and most feeding stations had rates of >50 bites/minute. As cattle probed under currant bushes for desirable forbs, biting rate was slow (25 bites/min). Biting rate while grazing the larkspur area was intermediate (25–50 bites/min). There was no significant trend (P>0.05) for increased biting rate over time (Table 5) even though the standing crop of graminoids and forbs besides larkspur declined (Table 1).

Animal movement rate (steps/min) differed by vegetation area (P<0.05) (Table 5). Cattle moved more rapidly while grazing the grass-forb area, slowest in the currant area, and intermediate in the larkspur area. No change (P>0.05) was detected in the step rate over time (Table 5). The grazing pattern of the heifers was similar throughout the study except during periods of heavy rainfall. Mean grazing time was 10 ha and 40 min. During a typical day the cattle grazed from 0200 to 0330, 0700 to 1035, 1340 to 1630, and 1830 to 2115 h.

Behavioral data indicated that cattle grazed more rapidly (i.e., higher bite rate and step rate) while in the open-grass forb areas. The bite rate:step rate ratio can be considered a crude index of foraging efficiency. Thus cattle grazed most efficiently in the grass-forb areas, least efficiently in the currant areas, and intermediate in the larkspur areas.

Discussion

Cattle consumed little tall larkspur during the initial days of the study, but bites of tall larkspur increased gradually to 15 to 30% by late August. Increased consumption of leaves was particularly notable, and coincided with a decline in leaf alkaloids with increasing plant maturity. Pod consumption appeared to be more a function of availability than of level of alkaloids, as pod apex TAC continued to increase over time.

TAC's found in this study were lower than those reported previously (Williams and Cronin 1966, Laycock 1975, Olsen 1978). Williams and Cronin (1966) found TAC in leaves of duncecap larkspur (*D. occidentale* S. Wats.) of 1.6% on 5 Aug. and 1.2% on 26 Aug. Alkaloid levels in apexes of duncecap larkspur were found to be of >2.0% during August. Work currently underway will determine year-to-year variation in TAC at this study site. The influence of variation of TAC on consumption of tall larkspur or on cattle deaths is not presently known.

Olsen (1978) collected tall larkspur of various growth stages and reported total alkaloid content of >2.0% on a whole-plant basis. He reported that a median lethal dose (LD_{50}) for cattle of this material was 2.48 g of larkspur per kg of body weight. Representative tall larkspur bite sizes (dry weight) in our study were 0.2 g for leaves, 0.8 g for flowering racemes, and 1.0 g for pod apexes. The maximum daily ingestion rate of tall larkspur we observed was 8,320 bites (80% leaves, 20% pods). Over the course of this grazing day the cattle would then have ingested about 3.0 kg of tall larkspur (1.33 kg leaves and 1.67 kg pods). Calculation from Olsen's (1978) study (TAC levels 2.2%, animal weights 160 kg) indicate that LD_{50} would have been about 0.9 kg of dry material. Had the tall larkspur in our study contained a higher concentration of alkaloids, this maximal number of bites would probably have been fatal, assuming higher alkaloid levels did not deter grazing.

There is much interest in plant secondary compounds as deterrents against herbivory (Provenza et al. 1987). Work at this laboratory indicates that cattle can be successfully averted from eating tall larkspur (Olsen and Ralphs 1986; Ralphs, unpublished data). On day 2 of this study, one heifer rapidly ingested a substantial but unknown quantity of tall larkspur, and was visibly distressed several hours later. Although this animal did not eat any tall larkspur for several days when her grazing cohorts were eating minor amounts, she subsequently began eating tall larkspur and provided no evidence of natural aversion.

Coley et al. (1985) have given a theoretical framework for relating herbivory, secondary plant compounds in plants, and environmental variables such as resource availability. This hypothesis relates high resource availability with high growth rate, relatively low levels of defense, and high rates of herbivory. Tall larkspur appears to fit this hypothetical framework, but empirical evidence is presently lacking. The hypothesis of Coley et al. (1985) will provide a background for future investigations with tall larkspur. In addition, we hypothesize that toxicity (and palatability) of *D. barbeyi* are related to plant phenology, as Olsen (1983) has indicated for *D. occidentale* toxicity using a mouse bioassay. Our observations indicate that tall larkspur is only palatable to most cattle after flowering. This is also when alkaloid concentrations begin to decline (Williams and Cronin 1966). Future work will also investigate factors triggering "gluttonous consumption", whereby

individual animals reportedly graze large and fatal quantities of larkspur when the plant is presumably high in alkaloids. Much work remains to be done to elucidate plant/animal factors involved in tall larkspur toxicosis.

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